Study on the Property and Microstructure of the Vitrified Bond Ni-coated CBN Composites in strong magnetic field

Zhelun Ma[1, a *], Tianbiao Yu[1,2, b], Xue Sun[1, c], Zixuan Wang[1, d]

[1]School of Mechanical Engineering and Automation, Northeastern University, NO. 3-11, Wenhua Road, Heping District, Shenyang, 110819, People's Republic of China

[2]Liaoning Provincial Key Laboratory of High-end Equipment Intelligent Design and Manufacturing Technology

[a]mzlneu@163.com, [b]tianbiaoyudyx@gmail.com, [c]sx114909@163.com, dwangzixuan.neu@gmail.com

Key word: vitrified bond, Ni-coated CBN, CBN composite, strong magnetic field.

Abstract: Mechanical property and microstructures of the vitrified bond Ni-coated CBN composites under different sintering methods are investigated. Vitrified bond was characterized using three-point bending, scanning electron microscopy, X-ray diffraction and other methods. Bending strengths, microstructures, and phase compositions of vitrified bond CBN composites achieved using conventional and strong electromagnetic sintering techniques were compared. Results show that the addition of Ni to vitrified bond CBN composites improved the fluidity. Ni-coated CBN abrasive improved the bending strength of vitrified bond CBN composites and changed the combined state of CBN abrasive and vitrified bond. Strong electromagnetic sintering improved the mechanical strength and pore structure of vitrified bond CBN composites.Moreover, strong magnetic field improved the combined state of Ni-layer and CBN, formed new substances, thus increasing the stability of vitrified bond CBN composite thermal material.

1. Introduction

The growing demand for hard materials in the industry due to their extensive range of applications has made it necessary to investigate their machinability comprehensively [1-3]. Due to high hardness, good chemical inertness, and good thermal conductivity, cubic boron nitride (CBN) grinding wheels are becoming one of the most potential grinding tools in manufacturing of modern engineering materials, especially ferrous materials. However, in certain grinding applications these vitrified bond CBN grinding wheels have demonstrated insufficient mechanical strength to meet commercial objectives [4-6]. In addition to the lack of bending strength of the vitrified bond, the bad combination of vitrified bond and CBN abrasive is also an important reason. Therefore, it is necessary to use surface-treated CBN abrasives in vitrified bond composites.

In previous studies, Malshe et al. [7] showed that the composite coating outperforms its industrial counterparts. Yu et al. [8] investigated that the effects of Ni addition and their contents on the mechanical properties and microstructures of vitrified bond CBN grinding tools. Li et al. [9] observed the microstructure of the CBN abrasives before and after titanium coating, and analyzed the effect of the Ti-coated layer on the strength of the ultra-high-speed grinding wheel. Wang et al. [10] coated the CBN abrasive grains uniformly through vacuum slow vapor deposition and observed the interfacial structure of the Ti-coated grains at different temperatures. With the application of coated CBN, the related preparation and performance testing of coated CBN abrasive grains have been paid attention to. However, the study of vitrified bond Ni-coated CBN composites can be supplemented. In this work, Property and microstructure of the vitrified bond Ni-coated CBN composites in strong magnetic field were evaluated.

2. Experimental procedures

2.1 Composites preparation

Boron aluminium silicate (SiO_2-Al_2O_3-B_2O_3-R_2O) was used in the experiment as the vitrified bond. The detailed chemical composition of the vitrified bond is shown in Table.1. Different types of CBN grains (CBN880, CBN880CN56, CBN880N56) were added to the vitrified bond, and the mixture was mixed evenly. The raw materials were weighed according to the designed proportions, mixed with deionized water (psychrometric ratio is 1:1), using wet ball-milling for 24h (ball-to-powder weight ratio is 4:1), placed in a drying oven (dying temperature is 100°C) until the water was completely evaporated, and crushed in a mortar and sieved through a 200-mesh sieve to obtain the vitrified base. Finally, the vitrified base was pressed with a universal hydraulic press （intensity of cold pressing is 60KN, dwell time is 3min）into 37mm × 6mm × 6mm cuboid specimens and stored in bags for further use.

Table 1 Composition of basic vitrified bond system (wt%)

SiO_2	Al_2O_3	B_2O_3	Na_2CO_3	Li_2CO_3
54.9%	8.84%	14.1%	9.07%	13.09%

2.2 Study methods

Conventional sintering was carried out in a chamber-type resistance furnace (SRJX-4-13A), and strong electromagnetic sintering was carried out with the equipment of superconducting strong magnetic fields (model JASTEC equipped with a superconducting magnet furnace, vacuum heating furnace, high power compressor, magnet power supply, and vacuum supply system). However, in order to keep the same gaseous environment, vacuum supply system is not applied to strong electromagnetic sintering. The mechanical properties of the vitrified bond are mainly described by bending strength. The bending strength was measured using a 3-point bending strength tester with a span of 20 mm at a crosshead speed of 0.5 mm/min. The microstructure of the sintered spline was observed using a scanning electron microscope (SEM, ULTRA PLUS).

3. Results and discussions

Three different types of CBN grains are used in the experiment. They are CBN880, CBN880N56 and CBN880CN56. CBN880N56 and CBN880CN56 are Ni-coated CBN grains, and coating method is chemical plating. Fig.1 shows the electron micrograph of ordinary abrasive and Ni-coated abrasive.

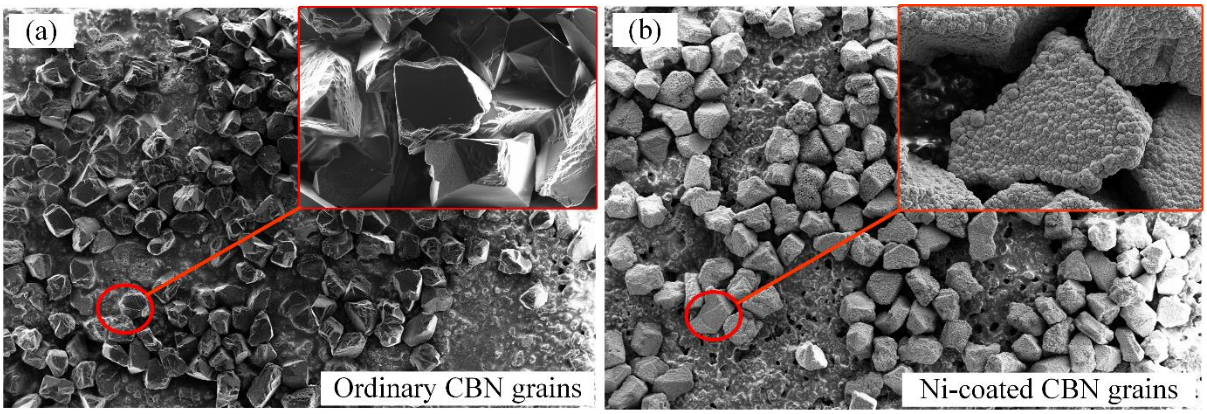


Fig. 1 electron micrograph of ordinary abrasive and coated abrasive

3.1 Bending strength

Bending strength is an important parameter to evaluate the mechanical properties of grinding tools. The values are closely related to the strength of vitrified bond and the combined state of vitrified bond and abrasive grains. Fig.2 shows three different types of specimens and bending strength (three values take average) of CBN composites with different CBN grains.

From the perspective of macro structure, the specimens with CBN880 grains were black, the surface was flat without obvious changes; the specimens with CBN880N56 grains were gray, the surface was not flat with different degrees of contraction; the specimens with CBN880CN56 grains were dark green, the surface had brown spots, and was not flat with obvious expansion.

From the bending strength of CBN composites, the specimens with CBN880N56 are highest, which reached 45.24MPa. Secondly, the bending strength of CBN composites with CBN880 grains was 41.63MPa. However, the bending strength of CBN composites with CBN880CN56 grains was only 24.39MPa. According to the phenomenon and bending strength, CBN880CN56 grains do not apply to vitrified bond. The coating of CBN880CN56 grains and vitrified bond react to produce gas and other substance, causing CBN composites to expand. Therefore, CBN880CN56 are not considered in this experiment.

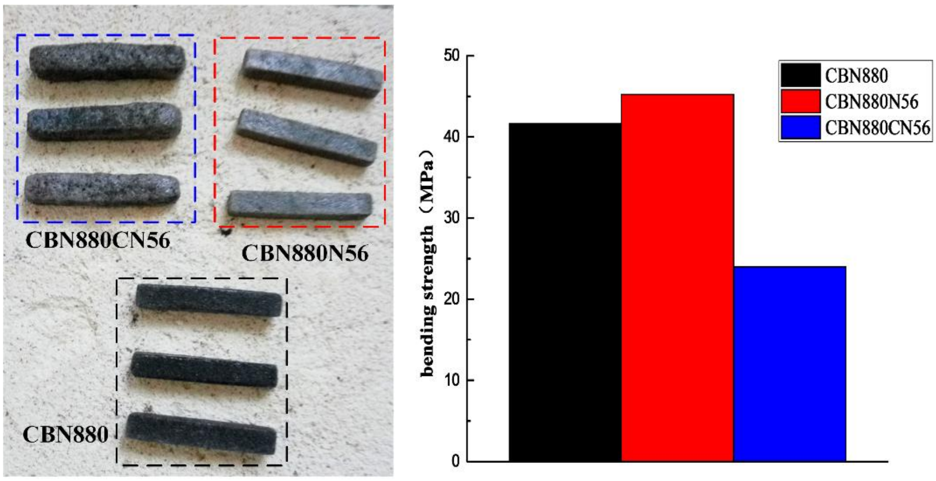


Fig. 2 bending strength of CBN composites specimens

In contrast to conventional sintering, the vitrified bond CBN composites were prepared by sintering in a strong magnetic field. The conventional and strong electromagnetic sintering techniques were compared by preparing vitrified bond CBN composites with different CBN grains. Due to limitations of experimental equipment, magnetic field intensity select 6T and 12T. The results are shown in Fig.3. When ordinary CBN grains are used in CBN composites, the bending strength of all the specimens subjected to strong electromagnetic sintering was higher than that of conventionally sintered specimens, the higher the magnetic flux density, the higher the bending strength. However, when Ni-coated CBN grains are used in CBN composites, bending strength of specimens produce opposite trend obviously. The higher the magnetic flux density, the lower the bending strength.

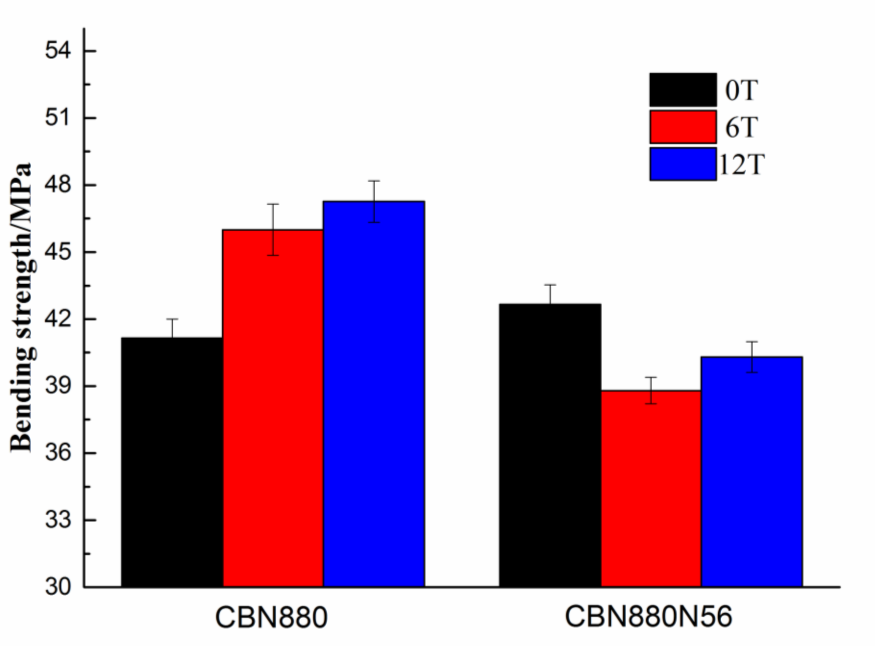
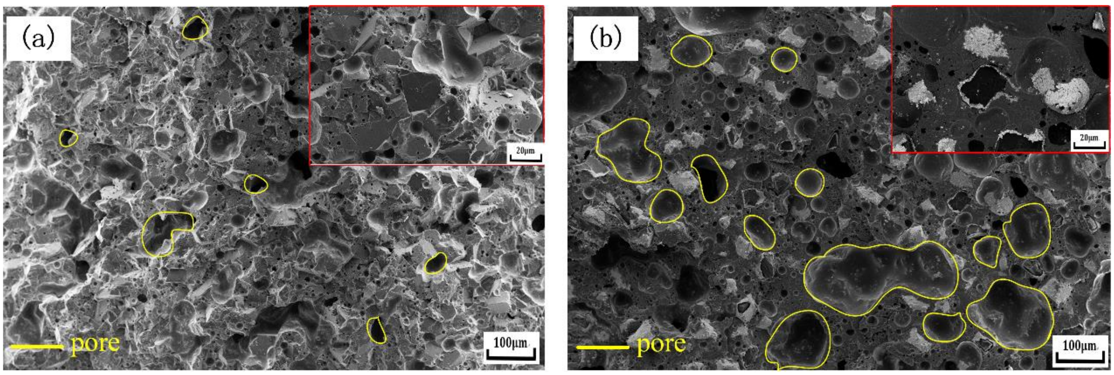


Fig. 3 bending strength of vitrified bond CBN composites with conventional and strong electromagnetic sintering techniques

3.2 Microstructure

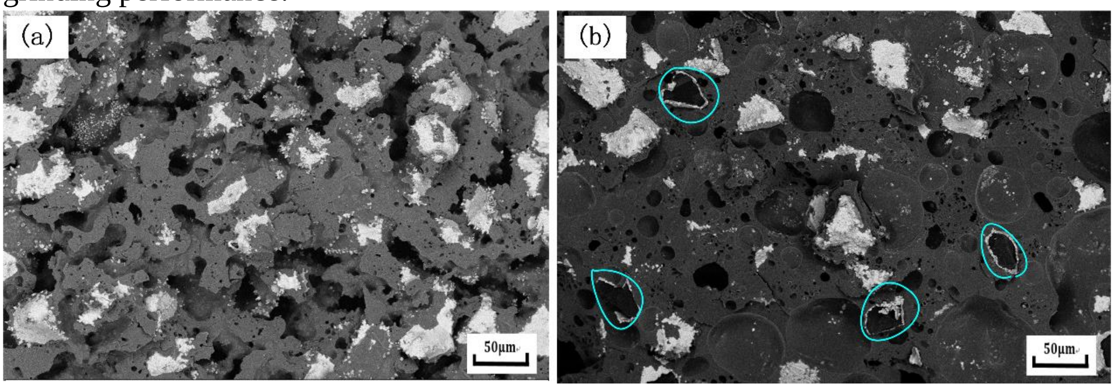


(a) SEM image of CBN composites with ordinary CBN grain, (b) SEM image of CBN composites with Ni-coated CBN grain

Fig.4 Sectional morphology of vitrified bond CBN composites

Fig. 4 shows the sectional morphology of vitrified bond CBN composites. Fig. 4(a) shows the micro-structures of CBN composites with CBN880 grains; Fig. 4(b) shows the micro-structures of CBN composites with CBN880N56 grains. As shown in Fig. 4, the pore structures of vitrified bond CBN composite shows two types of open pore and closed pore. Fig. 4(a) shows that the section was not smooth, and the surface had a lot of small pores, some open pores are distributed on the surface evenly. Fig. 4(b) shows a mass of closed pores are distributed on the section, the size is much larger than that in Fig. 4(a). However, though the pores number of CBN composites with Ni-coated grains is more than that with ordinary CBN grains, the bending strength of CBN composites with Ni-coated grains is higher than that with ordinary CBN grains. This phenomenon indicates the combination of vitrified bond and Ni-coated CBN grain improved significantly.

Fig. 5 (a) and (b) show the back-reflection image of vitrified bond CBN composites by conventional and strong electromagnetic sintering techniques. As shown in Fig. 5 (a), the CBN grains maintained good integrity, the coating on the abrasive particles was basically not falling off. This phenomenon indicates that there is no obvious change between the coating and the CBN grains in conventional sintering. However, as shown in Fig. 5 (b), a lot of abrasive grains had fallen off, the integrity of the Ni-coated CBN grain was destroyed. Because of the CBN composites were sintered in strong field, the coated nickel on the surface of the CBN grain was subjected to Lorentz force along the line of magnetic induction. This force acted on the periphery of the abrasive particles, causing the coating on one side to exert pressure on the abrasive particles and enhancing the direct bonding ability between the two. The Lorentz force on the other side causes the coating to break away from the abrasive particles, which destroys the bond between the two. When the CBN composite was broken, the abrasive grain and the coating would be disconnected where the bond was weak, so that the abrasive grains would be exposed. According to this phenomenon, in the process of grinding wheel production, the magnetic induction direction can be controlled so as to control the coating off position of the coated abrasive. During the dressing of the grinding wheel, the coating is repaired to expose the CBN; and the other part of the coating is connected with the vitrified bond to improve the combination between abrasive and vitrified bond. The inter-binding ability increases the grip of the vitrified bond on the abrasive so that the abrasive do not fall off easily, thereby improving the grinding performance.



(a) 200× back-reflection image of conventional sintered composites (b) 200× back-reflection image of strong electromagnetic sintered composites

Fig. 5 sectional morphology of vitrified bond CBN composites

4. Summary

(1) Three different types of CBN grains are used in this work. CBN880CN56 grains do not apply to vitrified bond. the bending strength of ordinary CBN composites subjected to strong electromagnetic sintering was higher than that of conventional sintering, the higher the magnetic flux density, the higher the bending strength. However, when Ni-coated CBN grains are used in CBN composites, bending strength of specimens produce opposite trend obviously. The higher the magnetic flux density, the lower the bending strength.

(2) In conventional sintering, the pore structure of CBN composites are changed. Because of the use of coated abrasive grains, the number of pores increased significantly. Open pores transformed into closed pores. In strong electromagnetic sintering, the existence of Lorentz force caused half of coating to fall off, on the other hand, it also improved the combination between the other half of coating and CBN grains.

Acknowledgement

This research was supported by Joint Foundation of the National Natural Science foundation of China (No. U1508206), the Fundamental Research Funds for the Central Universities (N160306006) and key laboratory project of Liaoning Province (No. LZ2015038), as well by key laboratory project of Shenyang City (18006001).

[1] C.S. Kumar, S.K. Patel, Effect of chip sliding velocity and temperature on the wear behaviour of PVD AlCrN and AlTiN coated mixed alumina cutting tools during turning of hardened steel, Surface and Coatings Technology, 334 (2018) 509-525.

[2] S.B. Hosseini, T. Beno, U. Klement, J. Kaminski, K. Ryttberg, Cutting temperatures during hard turning—Measurements and effects on white layer formation in AISI 52100, Journal of Materials Processing Technology, 214 (2014) 1293-1300.

[3] Y. Sahin, Comparison of tool life between ceramic and cubic boron nitride (CBN) cutting tools when machining hardened steels, Journal of Materials Processing Technology, 209 (2009) 3478-3489.

[4] D. Herman, J. Krzos, Influence of vitrified bond structure on radial wear of cBN grinding wheels, Journal of Materials Processing Technology, 209 (2009) 5377-5386.

[5] B. Zhao, Z. Li, Y. Zhu, Effect of polycrystalline mullite fibers on the properties of vitrified bond and vitrified CBN composites, Ceramics International, 39 (2013) 2863-2868.

[6] P. Klimczyk, P. Figiel, I. Petrusha, A. Olszyna, Cubic boron nitride based composites for cutting applications, Journal of Achievements in Materials & Manufacturing Engineering, 44 (2011).

[7] W. Jiang, A.P. Malshe, A novel cBN composite coating design and machine testing: A case study in turning, Surface and Coatings Technology, 206 (2011) 273-279.

[8] T. Yu, Z. Ma, X. Wang, B. Song, W. Wang, Effects of Ni addition on properties of vitrified bond CBN composites in strong magnetic field, Ceramics International, (2018).

[9] J. Li, Wang, Effect of Ti coating on cBN grains upon the bending strength of ultrahigh speed vitrified cBN wheel, Diamond & Abrasives Engineering, (2010) 77-80.

[10] Y.H. Wang, J.B. Zang, X.H. Zhang, M.Z. Wang, Interface bonding between Ti-coated cBN and vitrified bond, Grinding and Machining Conference, 2004, pp. 14-18.